

ACID RAIN SEEN IN NATURAL BUFFERS, PLANT GROWTH AND CORROSION OF NATURAL ROCKS OVER TIME

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Abstract— The present lab aimed to visualize the various effects of acid rain in different situations, including natural buffers, plant growth and rock resistance. The group analyzed three different scenarios using counter vinegar and CocaCola as a simulation to acid rain due to the high level of acidity in each of the liquids. The group understood that plant growth is slowed to completely stopped by acidic rain, leaving no traces of life whatsoever. Furthermore, the group concluded that natural buffers indeed help to reduce the effects of acid rain based on Ph levels compared to no buffers. Lastly the group understood that various rocks take time to degrade under natural conditions with Acidic rain.

I. INTRODUCTION

The following laboratory experiment was designed to observe the behaviour of various natural situations that acid rain may interfere with, such as plant growth, corrosion of various rocks or mountains and the natural buffers or elements that help slow down the processes of the acid rain. ***Glossary: Ph Level, Acidity of Liquids, Acid Rain, Buffer, Germination.***

II. OBJECTIVE

Investigate and observe how acid deposition affects natural systems by modeling it with weak, non-hazardous acids.

III. BACKGROUND

Acid rain is a type of acid deposition that happens when gases like sulfur dioxide (SO₂) and nitrogen oxides (NO_x), released mainly from cars and factories, mix with water and oxygen in the atmosphere. These reactions form sulfuric acid and nitric acid, which then fall to Earth in rain, snow, or fog. Normal rain is slightly acidic with a pH around 5.6 because of carbon dioxide in the air, but acid rain is much more acidic, often with a pH below. Acid rain affects ecosystems in many ways. It can lower the pH of lakes and rivers, making the water too acidic for fish, amphibians, and other aquatic life to survive. In soils, it removes important nutrients like calcium and magnesium while releasing harmful metals such as

aluminum. This weakens forests by damaging tree leaves and slowing growth.

Acid deposition also damages human-made structures. Buildings and monuments made of limestone and marble weather faster in acidic conditions, while metals corrode and paints wear away. Although acid rain itself doesn't harm people directly, the gases that cause it can lead to health problems like asthma and create haze that lowers visibility.

Studying acid rain is important because it shows how air pollution is connected to natural cycles of carbon, nitrogen, and sulfur, and how human activities can disrupt these cycles and harm both ecosystems and human structures.

IV. ROLES

White rabbit: Daniela was in charge of managing time in each station.

Dexter: Matias was in charge of keeping safe and clean the lab material and table during and after the practice.

Orchestra Director: Daniel Makes sure the instructions are followed as expected.

V. STATION I ROCK WEATHERING RATE

Question: How does acid rain affect different rock types?

Hypothesis—Rocks vary from size to composition, if different rock types are more prone to being dissolved on various substances, then chalk will be more prone to dissolve in any of the solutions.

Materials Used

1. 6 labeled cups
2. Rock samples: chalk/limestone and granite or quartz
3. 50 mL measuring cylinder
4. Solutions: distilled water, coke, vinegar
5. Balance
6. Filter paper or paper towels
7. Forceps/spoon

Procedure Followed

1. Measure and record initial rock mass (g).
2. Place each rock into a separate labeled cup.
3. Add 50 mL of assigned solution.
4. Observe for 10 min and score bubbling (0 = none → 3 = strong).
5. Leave for 24 h.
6. After 24 h:
 - Decant solution, measure pH, neutralize.
 - Remove rock, pat dry, measure final mass.
 - Record final pH.

Considered Variables

Independent: solution type (water, coke, vinegar).

Dependent: mass loss, bubbling, pH change.

Control: rock type, solution volume, exposure time.

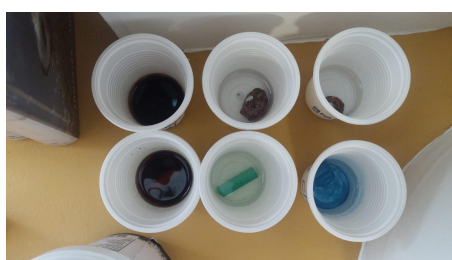
Result Table 1.1

Rock Type	Solution	Initial Mass (g)	Final Mass (g)	Delta Mass (g)	Effervescence (0-3)	Initial Ph	Final Ph
Quartz	Water	8.70g	8.6g	-0.1g	0	4.7	4.9
Quartz	Vinegar	10.8g	10.75g	-0.1g	0	4.8	5.1
Quartz	Cocacola	10g	9g	-1g	0	4	4.4

Result Table 1.2

Rock Type	Solution	Initial Mass (g)	Final Mass (g)	Delta Mass (g)	Effervescence (0-3)	Initial Ph	Final Ph
Chalk	Water	6.27g	5.89g	-0.37g	1	4.7	5.2
Chalk	Coke	6.45g	4.4g	-2.05g	2.5	4.8	5.5
Chalk	Vinegar	7.68g	5.5g	-2.17g	3	4	5.6

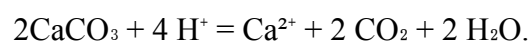
Picture 1.1

**Analysis:**

The chalk was the rock with the most bubbles and movement, the chalk started to dissolve quickly, and the water turned blue, the color of the chalk. The other rocks however did not change colors or dissolved rapidly. Acid rain takes more time to weather rocks and erode their elements into the river flows.

a) Which rocks lost more mass? Why?

Chalk, since they are made up of CaCO_3 and it dissolves on acids.

b) Write the balanced reaction for $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$.**c) Link reaction to the carbon cycle.**

As calcium carbonate reacts with the acid it reacts and becomes CO_2 gas and returns into the atmosphere so that the carbon cycle can begin again through photosynthesis.

VI. SOIL AND SEED GERMINATION

Question: Does acid rain affect soil quality and plant growth?

Hypothesis—If acidic solutions are applied, then the soil leachate will have a lower pH (more acidic) than the leachate from distilled water due to the concentration and composition of the acidic solution, leading to less growth for the plant.

Materials Used

1. 3 cups with ~150 g soil each
2. 5 seeds per cup
3. Solutions: distilled water, coke, vinegar
4. pH meter
5. Ruler

Protocols Followed

1. Label cups (Water, Coke, Vinegar).
2. Plant 5 seeds per cup.
3. Day 0: add 15 mL solution.
4. Days 1–2: add 15 mL solution each day.
5. Collect leachate, test pH daily.
6. Day 3–5: record germination count.
7. Measure root length of 5 seedlings, record mean.

Variables Considered

Independent: solution type.

Dependent: germination %, mean root length, leachate pH.

Control: soil amount, seed type, water volume.

Results Table 2.1

Treatment	Day	#Germinated	%Germinated	Growth mm	Total Growth
Water	1	0	0	0mm	0mm
Water	2	0	0	0mm	0mm
Water	3	0	0	0mm	0mm

Results Table 2.2

Treatment	Day	#Germinated	%Germinated	Growth mm	Total Growth
Coke	1	0	0	0mm	0mm
Coke	2	0	0	0mm	0mm
Coke	3	0	0	0mm	0mm

Results Table 2.3

Treatment	Day	#Germinated	%Germinated	Growth mm	Total Growth
Vinegar	1	0	0	0mm	0mm
Vinegar	2	0	0	0mm	0mm
Vinegar	3	0	0	0mm	0mm

Image 2.1—Growth by day 3 after 2 days of watering



Analysis

The growth was not seen for the first week the experiment was conducted. The group inferred this might be due to the slow growth of the selected seeds, the lack of proper sunlight in the classroom or the cold air that the location chose has at those times.

The group saw the results of other groups and understood that acid rain indeed damages the roots, limiting the growth and killing the plants, as the vinegar and coke seedlings were dead by the third or fourth day of analysis.

a) Compare germination rates. None of the plants germinated from the seeds, the group considers the seeds or the soil might be faulty, or the amount of time was not enough to measure the growth.

b) Which nutrients leach under acidic watering? Acidic watering leaches vital nutrients like potassium, calcium, but most importantly can help accelerate the nitrate leaching of plants.

c) Effects on nitrogen/phosphorus cycles. The process of acidification makes nitrate easier to leach and dissolve and acidify even further the soil, also low pH in soil essentially traps phosphorus and makes it so that plants can't uptake it, disrupting both the phosphorus and nitrogen cycle.

VII. AQUATIC BUFFERS

Question: How do natural buffers protect water bodies from acid rain?

Hypothesis—Buffers are found in various ways naturally around various biomes, and tend to vary in concentration. If natural buffers are added in more or less amounts, then the buffering capacity will increase or decrease respectively.

Materials Used

1. 3 beakers (200 mL water each)
2. Coke, vinegar
3. NaHCO_3 solution or crushed eggshells
4. Graduated cylinder (2 mL)
5. pH meter, stir rod

Procedure Followed

1. Prepare:
 - Beaker A: water only
 - Beaker B: $+\text{NaHCO}_3$
 - Beaker C: $+\text{eggshells}$
2. Record initial pH.
3. Add 2 mL vinegar → record pH (0, 1, 3, 5 min).
4. Add another 2 mL vinegar → repeat.
5. Compare resistance to pH change.

Considered Variables

- Independent: buffer type.
- Dependent: pH stability.
- Control: water volume, vinegar amount, timing.

Results Table 3.1

Type	I. Ph	Ph Pulse 1 0/1/3/5	Ph Pulse 2 0/1/3/5
Water	7	4/3.9/3.8/3.8	3.5/3.5/3.8/4
NaCO ₃	8.1	7/7.1/6.8/6.9	6.7/6.7/6.8/6.8
Shells	7.5	4.6/4.5/4.4/4.3	4.1 / 4.1/ 4 / 4

Analysis

The group decided to compare the results with other groups that did the same experiment but with coke as their acid rain.

The group saw that the natural buffers indeed help reduce or slow down the impact of the Acid rain, as the Ph level was low by each basing pulse, and the buffers indeed help reduce the impact.

The group however wonders if the amount of egg shells used was enough to truly see its effects, as it was eye measured to half a teaspoon.

a) Which buffer resisted pH change best?

The buffer which resisted the change best

was the NaCO₃ since it showed the smallest change from its initial pH.

b) Chemical role of buffer in neutralizing H^+ . The role of buffers is to prevent big changes in pH, neutralizing the ions by releasing the conjugate or opposite.

c) Importance of buffering in aquatic ecosystems. Buffers maintain the ecosystem's pH and ensure biological processes can function since pH is a limiting factor, and changes in it disrupt the ecosystem.

VIII. GENERAL ANALYSIS

How acid rain disrupts biogeochemical cycles (carbon, nitrogen, phosphorus, water).

Acid rain disrupts biogeochemical cycles such as the carbon, nitrogen, phosphorus, and water cycles by changing how matter moves through ecosystems. In the carbon cycle, acid rain speeds up decomposition, which releases more carbon dioxide, and damages plants, which reduces photosynthesis. It also dissolves carbonate rocks, affecting how carbon is stored, as seen in station 1. In the nitrogen cycle, acid rain adds too much nitrogen in the form of nitric acid. At the same time, soil acidification reduces the activity of bacteria and causes nitrate leaching, which

lowers soil fertility and leads to eutrophication in lakes and rivers. The phosphorus cycle is also disturbed because acidic soils bind phosphorus to metals like aluminum and iron, making it unavailable to plants. In water, phosphorus can get trapped in sediments, which reduces productivity. Finally, acid rain affects the water cycle by lowering the pH of rivers and lakes, releasing toxic metals, and overwhelming natural buffering systems. This harms aquatic life and contaminates water supplies.

Long-term effects on forests and lakes.

In areas affected by acid rain, dead or dying trees are frequently seen. Aluminum is leached from the soil by acid rain. Both plants and animals may be harmed by that aluminum. Additionally, acid rain gets rid of the soil's nutrients and minerals that trees require for successful growth.

Acidic clouds and fog at high elevations might rob trees' leaves of nutrients, leading to brown or dead leaves and needles. The trees become weaker and less resistant to freezing temperatures as a result of their decreased capacity to absorb sunlight.

Additionally, in aquatic ecosystems like lakes, streams, and marshes, where it can

kill fish and other wildlife, acid rain's ecological consequences are more evident. Rainwater with an acidic pH can dissolve clay particles in the soil, releasing aluminum into streams and lakes. Aluminum is released in proportion to the amount of acid added to the environment.

Human activity contributing to acid rain + mitigation strategy.

Most acid rain is caused by human activity. The largest sources include factories, cars, and power plants that burn fossil fuels.

Sulfur dioxide (SO₂) and nitrogen oxides (NO_x) are released into the atmosphere when fossil fuels are burned. Airborne sulfuric and nitric acid are created when such air pollutants combine with oxygen, water, and other materials.

These acidic substances can move hundreds of miles across the sky thanks to winds. When acid rain hits Earth, it enters water systems, travels across the surface as runoff water, and then settles in the soil.

Reducing the discharge of the chemicals that cause acid rain is the only effective way to mitigate it. This involves creating air quality standards and using fewer fossil fuels.

Acid rain was the focus of the Clean Air Act of 1990 in the US, which established pollution limitations that contributed to a 92% reduction in sulfur dioxide emissions between 1990 and 2023. In the same period of time, U.S. nitrogen dioxide emissions have decreased by 55% due to air-quality regulations. The past few years have brought an even greater reduction in emissions thanks to programs like the Environmental Protection Agency's Acid Rain Program.

Advanced Investigation

Why lakes respond differently (alkalinity, geology).

Unlike rivers, lakes are usually still. Although some rivers are made by the water that comes from the flow of rivers or streams others are mainly filled by the precipitation in certain areas. The Florida Everglades are made up by various lakes that follow these characteristics, meaning that the rain that they receive tends to be more acidic than in other regions in North America. Acidic rain that forms in the biome is due to the high levels of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) in the air and their interference with the precipitation before entering the Floridian peninsula. The water that arrives to the

still lakes with no streams that flow into them tends to store these acidic levels, and over time the amount of acidity gets pulled and infiltrated into the soil and sediments below the lake, leaving more impregnation of those acidic elements into the lakes. While streams tend to move the water, not allowing for it to get stored in the bottom layers for multiple rainy seasons.

Propose lab improvements.

The lab could be improved by adding different elements to simulate acidic rain. Although using acids can be dangerous it can provide a better view of how the acid breaks down the soil or the rocks that it touches in a shorter amount of time. Furthermore, the lab could be improved by focusing on longer periods of time and the impact of the acid rain on them, to really see how they get affected. Another interesting way to see how acid rain affects the solid could be to use a clear container to see how the acid rain kills the roots and how it damages the soil over time.

Relate to SDGs 3 (Health) and 11 (Sustainable Cities).

It is important to understand how health can be affected over time. The SDG number 3 aims to provide quality healthcare access to every single person in

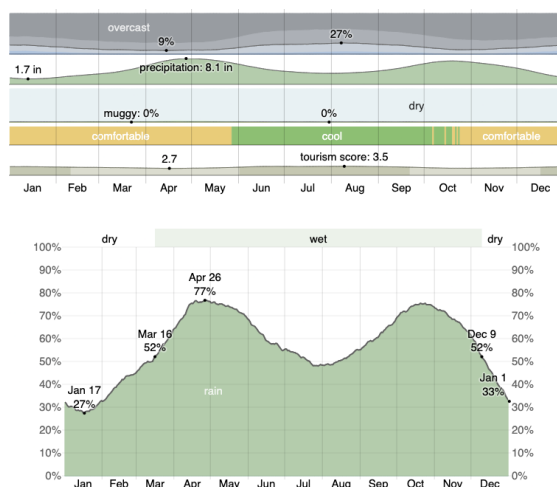
the world. The experiment is good to see how acid rain can damage crops, alter lung health or cause diseases over time for those who are constantly being affected by the phenomenon.

The SDG number 11 aims to have cities that are green and sustainable, with better access to public services and good quality of life for everyone present. The experiment is also good to see how cities can implement buffers and avoid the creation of acid rain by moving to public transport or limiting factories and industrial damaging activity.

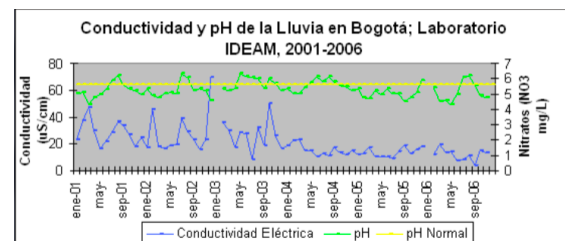
IX. MASTERY INVESTIGATION

Compare with local rainfall pH or emissions data.

In Chía Cundinamarca Colombia the average precipitation can be seen in the following graph



The highest points or the biggest amount of precipitation fall within the March through May trimester for the beginning of the year, around “summer time” which isn’t really summer since Colombia has no seasons whatsoever, the precipitation is lower, and in the beginning of August until November the precipitation rises again, going to an average low point from december to january, raising again by february.



According to the Institute of Hydrology, Meteorology and Environmental Studies from the year 2001 until 2006 the average Ph and the Ph reported for the rainfall has stayed consistent, but experts argue that acid rain may enter the central regions of Colombia due to the rising industries that emit deadly fumes to the atmosphere. Electrical conductivity means the normal hydrogen cycle, where in the central region of Colombia certain thunderstorms have been reported ultimately.

Analyze Rochester WWTP’s role in the water cycle.

Rochester School's Waste Water Treatment Plant ensures that certain contaminants from the grey waters can be reduced before reentering the cycle. The plant ensures that solids and liquids are separated, and also measures the average Ph of the water before allowing it to go back to the natural cycle. The plant helps to separate other non biological pollutants like paper or sanitary pads that may end up in the waterways and in the environment.

It is important to remember that the WWTP allows a portion of the water, but the school still needs to pay for fresh water from the public services, mainly for cooking or consumption of the students in the water fountains.

X. GENERAL CONCLUSIONS

The group understood that acid rain can be deadly in the long term. The constant endurance can be damaged as acid rain can break down roots not allowing for them to grow fully and complete their cycles like the hydrogen cycle.

The group recommends that deadly fumes that cause acid rain are ultimately reduced from being released to the atmosphere, looking for more green alternatives is the ebay to grow to avoid the damage of crops or human activity in the long run.

The experiment helps to understand how human activities can be changed with small actions to lower the amount of fossil fuels produced and look into the bigger scope before buying or using products that may cause these deadly fumes to get out into the atmosphere. The group recommends buyers to look for products with the following labels: CarbonFree® Product Certification, Climate Pledge Friendly, The Carbon Trust or Blue Angel as an example. These labels can be found in certain products and indicate low Co2 or deadly gas emissions into the atmosphere at the moment of fabrication of their products.

The group also recommends avoiding visiting places with rocks that contain really high levels of calcium, magnesium, or potassium, meaning exposed rocks or soil that has been lifted and moved. These minerals are natural buffers and visiting set places or using the areas where there are high concentrations of them could lead for their effects as buffers to get lowered.

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